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Loudspeaker protection system having frequency band selective audio power control.

The present invention relates to a loudspeaker protection system comprising filter means for defining one or more frequency bands of an audio signal.

The present invention also relates to a audio set provided with a loudspeaker protection system.

Such a loudspeaker protection system is known from DE-AS 24 15 816 and can be applied in compact, small size, so called micro, mini or midi audio sets. The known loudspeaker protection system comprises respective bandwidth controllable filter means, whose individual bandwidths in particular in the low and high frequency bands are controllable by means of a control means coupled to the loudspeaker of the system. In order to thermally protect the loudspeaker against short or long lasting overload the filter means can be influenced by decreasing the output level of the audio signal for the loudspeaker. Merely decreasing the loudspeaker output level within e.g. a bass frequency range may provide some protection, but at the same time it is a disadvantage of the known loudspeaker protection system that it sacrifices loudspeaker output power unnecessary and thus fails to make effective use of available loudspeaker output power. In addition this sacrifice of output power is a major commercial disadvantage in particular for the young aged target group of these audio sets.

Therefore it is the aim of the present invention to provide a loudspeaker protection system, which is made effective for the specified purpose of protecting the loudspeaker only, without unnecessary effecting the full power range available for the loudspeaker.

Thereto the loudspeaker protection system according to the present invention is characterised in that the loudspeaker protection system further comprises controllable amplifier/attenuator means coupled to the filter means, and processing means coupled to control the amplifier/attenuator means, such as to determine audio power in at least one of said

frequency bands representing relevant loudspeaker protection information used for selective audio power control in said at least one frequency band.

By determining the respective audio output powers for the loudspeaker in respective frequency bands accurate information comes available about the variety of sources of dangers which are connected to loudspeakers, such as short and long term overload, as well as excessive excursion or displacement of the loudspeaker cone or coil, which is a well known source of all kinds of distortion in reproduced loudspeaker sounds. Thus a multi-purpose loudspeaker protection system is made available, which can be dedicated to its specific protection functions without unnecessary effecting the full power range available for the loudspeaker. Audio power in respective frequency bands has thus proven to provide a reliable source of loudspeaker protection information so that no audio output power is sacrificed needlessly and the maximum audio output performance can be delivered without endangering the loudspeaker.

One embodiment of the loudspeaker protection system according to the invention is characterised in that the processing means are equipped to determine the audio power $S_j$ in frequency band j in proportion to:

$$v_{jtop}^2 * R\{Y_j\},$$

where $v_{jtop}$ is the peak value of the amplitude of the frequency components in frequency band j, and $R\{Y_j\}$ is the real part of the electric admittance of the loudspeaker in frequency band j.

Advantageously $v_{jtop}$ can be derived from the respective outputs of the amplifier/attenuator means and $R\{Y_j\}$ can either be estimated or predicted, or can more accurately actually be measured in a further embodiment by means of a measuring element arranged in series with the loudspeaker.

A further embodiment of the loudspeaker protection system according to the invention is characterised in that in the loudspeaker protection system j = 1, 2, 3 ... n, where n equals the number of frequency bands wherein the frequency spectrum of the audio signal is divided.

Starting with j = 1, which is the frequency band containing the lowest frequency components of the audio signal, this band contains relevant information, which is a good estimate for the resistance of the voice coil of the loudspeaker. This resistance depends on and generally increases with the actual temperature of the voice coil. So the information contained

in $S_1$ may be used to activate the amplifier/attenuator means to function as a slow term thermal protection. Similarly $S_2$ for example containing frequency components around the so called Helmholtz frequency (e.g. between 25 Hz and 85 Hz for a bass reflex loudspeaker system) provides accurate information about the actual excursion of the cone of the loudspeaker. So the information contained in $S_2$ may be used to activate the amplifier/attenuator means to function as a fast cone excursion protection.

A still further embodiment of the loudspeaker protection system according to the invention is characterised in that the processing means are capable of summing $S_j$ over a specified subrange of possible values of j, where j is in the range from 1, 2, ... n.

Advantageously summing $S_j$ over possibly all values from 1 to n reveals a value of S which represents information about he momentaneous electrical dissipation in the loudspeaker. So the information contained in S may be used to activate the amplifier/attenuator means to function as a fast thermal protection.

In practise some sensible and fast enough summed value or combination of values $S_j$ will be used so that if these respective values approximate some normalised individual value $S_{norm}$ the amplifier/attenuator means are controlled by the processing means to take proper action to protect the loudspeaker.

By in a still further embodiment of the invention determining $S_j$ or any summation thereof every 0.001 - 2 sec., in particular every .1 - 1 sec updated data are derived such that an accurate and reliable protection is available at all times. Advantageously the present invention can be applied not only in the low frequency range for bass loudspeakers, but also for mid-tone and high-tone loudspeakers.

Principally various values and value control methods are possible for the amplifier/attenuator means but preferably in another embodiment of the loudspeaker protection system they are controlled such by the processing means that attenuation factors of the amplifier/attenuator means are proportional to:

$$1 / \sqrt{\alpha} + \beta_j (1 - 1 / \sqrt{\alpha})$$

where $\alpha = S / S_{norm}$, and $\beta_j$ represents a factor whose value depends empirically on the particular frequency band j.

Still another embodiment of the loudspeaker protection system according to the invention is characterised in that the loudspeaker protection system comprises a series arrangement of the loudspeaker and a measuring element such as a resistance, whose common connection point is coupled to the processing means to account for actual impedance data of the loudspeaker.

Advantageously measurement of actual impedance data of the loudspeaker improves reliability and accuracy of the protection system.

It is preferred that the processing means is arranged to initiate control in a shorter amount of time than that control is withdrawn.

Advantage thereof is that this way of starting and completing control is less audible and disturbing for the human ear.

At present the loudspeaker protection system according to the invention will be elucidated further together with its additional advantages while reference is being made to the appended drawing. In the drawing:

Fig. 1 shows a schematic representation to illustrate possible embodiments of the loudspeaker protection system according to the present invention; and

Fig. 2 shows graphs of the impedance versus frequency of two types of loudspeakers.

Fig. 1 shows a possible loudspeaker protection system 1. The system 1 comprises an audio signal input terminal 2 connected to a possible dividing amplifier A0, which is connected to a parallel arrangement of filter means of the system 1, which filter means are arranged as bandpass filters BPF1-BPF(n-1), and possibly BPF(n), whereby the latter may be a highpass filter. Each of the respective filter means BPF is connected to controllable amplifier/attenuator means, shown as separate amplifiers A11-A1(n) and attenuators A21-A2(n). Each of the amplifier/attenuator means is provided with a control input Vc1-Vc(n), such that the amplification or attenuation of the amplifier/attenuator means can be controlled in dependence on the respective control signals there on. Output signals designated v1-v(n) are input to an adder 3, which in turn is connected to an amplifier A3 and then to a loudspeaker LS, which is coupled to earth. The system 1 comprises processing means 4 fed by the output signals v1-vn through peak-value detectors P1-Pn. The peak-value detectors P1-Pn finally input signals V1-Vn, which are representative for the peak value of the output signals

v1-vn. The processing means 4 provide control signals Vc1-Vc(n-1) to the correspondingly designated control inputs of the amplifier/attenuator means. Additionally in a further embodiment of the loudspeaker protection system 1 further control information may be derived from a measuring element, such as a resistor Rm, which through a further bandpass filter BPMm, an amplifier Am and a further peak detector Pm, which control information is also conveyed to the processing means 4. Principally all constituting elements of the loudspeaker protection system 1 can be implemented in either an analog, or digital, or hybrid way, whereby conversion takes place by means of suitable A/D and D/A convertors and, where possible, multiplexers are applied to reduce the number of necessary convertors. The processing means 4 can be implemented by means of a properly programmed processor, such as a microprocessor or computer.

The functioning of the loudspeaker protection system 1 is as follows. The audio signal on input terminal 2 is divided in separate frequency bands by the filter means BPF1-BPFn. The audio power $S_j$ in each of the frequency bands j is being calculated repeatedly by the processing means 4 in the embodiment as shown as:

$$S_j = v_{jtop}{}^2 * R\{Y_j\} * (A_3)^2,$$

where $v_{jtop}$ is the peak value of the amplitude of the frequency components in frequency band j, $R\{Y_j\}$ is the real part of the electric admittance of the loudspeaker in frequency band j and $A_3$ is the gain of amplifier A3. The latter may come from a table with premeasured data concerning the electric admittance of the loudspeaker LS concerned or may be actually measured by means of the measuring element Rm, which will be elucidated later. The number n of frequency bands may for example be between 2 and 8. The lowest frequency band contains information in the form of the audio power $S_1$ present therein, which is a good estimate for the resistance of the voice coil of the loudspeaker. This resistance increases with the actual temperature of the voice coil. If in an audio signal at a certain moment $S_1$ exceeds a normalised loudspeaker value $S_{norm}$ then the amplifier/attenuator means are activated by the processing means 4 and the control signal Vc1 is influenced to decrease the power $S_1$, which reduces critical audio power to the loudspeaker, such that a long term (slow) thermal protection thereof is achieved. The output power $S_1$ is controllably reduced as far as necessary for protection of the loudspeaker LS, whose full power range can thus safely be used.

Similarly $S_2$ for example containing frequency components around the so called Helmholtz frequency and above (e.g. between 25 Hz and 85 Hz for a bass reflex loudspeaker

system) provides accurate information about the actual excursion of the cone of the loudspeaker. An example of an Helmholtz band and Helmholtz frequency $f_H$ is shown in fig. 2 between $f_1$ and $f_2$. The one peak curve as shown is representative for a normal loudspeaker system. So the information contained in $S_2$ in the form of audio output power around the Helmholtz frequency may be used to activate the amplifier/attenuator means to function as a fast cone excursion protection. If the audio power in $S_2$ exceeds a predetermined level then this is an indication that the voice coil moves out of its magnetic field and an unwanted large excursion arises. Cone protection is achieved by allowing the processing means 4 to control the output power in $S_2$ such that it is lowered to an extend that said predetermined level is not exceeded for the particular loudspeaker. Offcourse any suitable combination of frequency bands $S_j$ may be used and/or summed to provide the wanted information about excessive cone excursions.

The following protection that may achieved is a long range or fast thermal protection protecting against high-level peaks in the audio signal for the loudspeaker. this can take place by determining in the processing means 4 the sum S of output power $S_j$ in several frequency bands by:

$$S = \Sigma\, v_{jtop}^2 * R\{Y_j\} * (A_3)^2.$$

If S exceeds a further normalised predetermined value then control action is taken by the processing means such that finally S decreases and the summed, possibly total audio power in the loudspeaker decreases, which protects the loudspeaker LS against momentaneous high-level audio peaks. The processing means are capable to determine $S_j$ or any summation S thereof every 0.001 - 2 sec., in particular every .1 - 1 sec. This will generally depend on the expected variations in the audio signal and on the speed of the hardware and software needed to program the processing means 4 properly. Of course any of the above described protection methods may be combined and performed in any obvious way for either bass, mid-tone, or high-tone loudspeakers.

Control of the attenuation factors Vc1-Vcn will take place gently in order not to attenuate the audio signal to much, and such that the full power range of the loudspeaker LS is still usable. A possible way of control is that the amplifier/attenuator means are controlled such by the processing means that the attenuation factors of the amplifier/attenuator means are proportional to:

$$1 / \sqrt{\alpha} + \beta_j (1 - 1 / \sqrt{\alpha})$$

where $\alpha = S / S_{norm}$, $S_{norm}$ represents the further normalised predetermined value of S, and $ß_j$ represents a factor whose value depends empirically on the particular frequency band j. For example $ß_j$ may be chosen 0, 1/4, 2/4, 3/4, 1. Herein S may be summed over one or more frequency bands. For example attenuation (or inverse amplification) in the amplifier/attenuator means can even more gradually be adjusted proportional to:

$$\{\tau^x + ß_j(1 - \tau^x)\}\{1 / \sqrt{\alpha} + ß_j (1 - 1 / \sqrt{\alpha})\}$$

where for fast thermal protection $\tau$ exceeds 1 and x is a constant to be determined empirically. Generally it is preferred for human perception reasons that the processing means 4 are arranged to initiate control in a shorter amount of time than that the control is withdrawn.

In the above mentioned further embodiment the loudspeaker protection system 1 comprises the measuring element Rm. The data concerning the momentaneous impedance and voltage across the element Rm on for example common connection point P can be used by the processing means 4, instead of corresponding data in a memory table of the processing means 4 to have actual and thus more accurate and reliable values available for each possible combination of the above mentioned protection methods.